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THE LEVEL AND STRUCTURE OF SINGLE VOYAGE  
FREIGHT RATES IN THE SHORT RUN

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ABSTRACT

The oil-tanker markets have been for years a puzzle to economists and practitioners alike. Tinberger (1934), Koopmans (1936) and Zannetos (1966) observed a cyclicality in the level of tanker rates and "feast or famine" patterns which cannot be fully explained by a cyclical demand. Zannetos (1966; 1975; 1976) provided evidence linking these phenomena to price-elastic expectations by those who operate in the tanker markets and to the concomitant lumpiness in investment in new tankers.

With the advent of the supertankers, especially the Very Large Crude Carrier (VLCC) and the Ultra Large Crude Carrier (ULCC), another paradox has been added, that of a structure of spot rates.

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\* This paper is based on the first author's thesis entitled "Transportation Costs and Oil Prices" which was submitted in partial fulfillment of the requirements for the Master's degree in Management at the Massachusetts Institute of Technology in February 1978, and the second author's continuing research in short-term and long-term tanker rates.

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The purpose of this paper is to shed some light on this last issue.

A statistical model is constructed describing spot freight rates in terms of the operating costs of the marginal ship, the size of the various vessels relative to the marginal ship, the proportion of the tanker fleet operating in the spot market and the proportion of the fleet which is laid-up for more than two months.

The model developed is validated by using the empirical data of the entire period from September 1971 to December 1976, and also the stratified data of shorter periods characterized by either abnormally high or abnormally low rates. Based on these results, a measure of the economies of scale for tankers for different sizes is developed, and the proportion of these economies which is enjoyed by the shipowner, under various market conditions, is calculated.

## I. BACKGROUND

### A. The Supply and Demand for Tankers in the Short Run

The demand for tanker capacity is derived from the world demand for oil. The ocean tanker is the only meaningful means for oil transportation between countries separated by oceans, and the future demand for crude oil is the most important investment consideration for the tanker owner.

Because of this, and in a world where oil prices are fixed by a monopolistic cartel and pricing decisions are inextricably mixed with politics, one may conclude that conditions favoring administered pricing schemes would be prevalent also in the tanker markets. If this were the case, a model describing freight rates purely in terms of demand for oil would, most probably, exhibit a large variance and, consequently, be of limited predictive value.

For several reasons, the tanker markets do not behave like the oil markets. It was pointed out elsewhere (Zannetos 1966, Chapters 7 and 8; 1973; 1975)<sup>1</sup> that for theoretical and institutional considerations we observe in the tanker markets behavior resembling, in the short run, perfect competition. The primary reasons for this phenomenon are:

- (a) the physical mobility of the capital invested in tankers because the latter can move from one geographic market to another with ease,
- (b) the relatively low cost of entry into and exit from the industry,
- (c) the extensive economies of scale which accrue with the increasing size of tankers,
- (d) the very modest economies which are realized with the size of the fleet making thus the vessel as the focal point of the firm,
- (e) the size of the total tonnage required as compared to the average size of the vessel thus creating conditions of low industrial concentration and,
- (f) finally, the absence of any significant barriers to entry.

The short run behavior of those operating on the supply side of the tanker markets is primarily governed by the balance between the demand for tonnage and the tonnage seeking employment at any moment

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<sup>1</sup>The last five years have provided no evidence which invalidates the findings reported in the referenced publications. On the contrary, the recent behavior of the tanker markets has been predictable and consistent with past behavior.

in time. As a result, fluctuations in the demand for oil which may not necessarily affect oil prices,<sup>2</sup> may cause significant changes in the structure and level of tanker rates.<sup>3</sup>

Because of the nature of the uses of oil, convincing theoretical arguments may be advanced, and the experience of the last few years verifies, that the aggregate demand for oil especially in the short run, is highly price inelastic.

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<sup>2</sup>Because of the ability of OPEC to restrict production and eliminate surpluses, oil prices stay constant or may even rise in the face of oil glut. Furthermore, several OPEC countries have come to the point where they have surplus funds and as a result the higher the oil prices the less they have to produce to satisfy their needs, giving rise to a "backward bending supply curve". See August 27, 1980 Wall Street Journal, p. 21 and September 12, 1980, p. 25. Also Boston Globe, September 12, 1980, p. 31.

<sup>3</sup>We have evidence of this contrast in the following quotes from the "press". On July 1, 1980 (Wall Street Journal, p. 26) it was reported that Kuwait decided to raise the price of its crude by \$2.00 per barrel in spite of surpluses. Of course, most of the OPEC price-increases in the last seven years have been in the face of crude surplus. In contrast, E. A. Gibson (July 18, 1980) reports that tanker rates "plumbed new depths," because of a large number of vessels "competing for a much reduced quantity of oil to be transported." Since then, again according to Gibson (September 5, 1980), "somewhere in the order of 40 vessels in excess of 9 million dead-weight tons" have been committed to storage.

In spite of the relative price insensitivity of the quantity of oil demanded, fluctuations in the aggregate demand for oil do occur for seasonal reasons, causing in turn fluctuations in the demand for ocean transportation.<sup>4</sup> But, and even if the aggregate demand for oil were to be constant, shifts in the lifting of crude oils from one producing country to another are not unusual. A decrease in the crude shipments of one country, and even if it is exactly offset by an increase from another country, will affect available tanker capacity if the transportation intensity of the two crudes to a given destination is different.<sup>5</sup>

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<sup>4</sup>Also the anticipation of price increases for oil, naturally creates a flurry of buying, as oil companies and other oil users try to take advantage of the prices prevailing at the time. As a result the demand for transportation capacity may increase, causing in turn an increase in tanker rates.

<sup>5</sup>Whenever oil surpluses exist, it is not unusual for such shifts to occur. Furthermore, shifts may occur in the consumption patterns of importing countries. All these variations in oil demand cause fluctuations in tanker capacity utilization and concomitant fluctuations in tanker rates. The rate fluctuations may not be identical at any moment in time, for all segments of the market (Arabian Gulf; West Africa; Mediterranean and Caribbean) but tend to be equalized over time, as vessels move from one market segment to another.

Short of a period long enough for shipbuilding, the supply of tankers beyond a certain level close to full capacity is also highly inelastic.<sup>6</sup> Finally the size composition of the tanker fleet must be considered fixed in the short run, although for the very long run it has been changing as more VLCC (Very Large Crude Carriers) and ULCC (Ultra Large Crude Carriers) enter into the market and replace the older and normally smaller vessels. Prior to 1966, there were no vessels in the 160,000 DWT category and above. (See Jacobs pp. 40 - 41). Although the trend toward ever larger vessels has been halted, 23.24% of all tankers representing 60.64% of total capacity were over 16,000 DWT on January 1, 1980. (See Jacobs pp. 6, 40, 41)<sup>7</sup>

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<sup>6</sup>The short-term supply schedule turns from elastic to inelastic around 94% of full capacity utilization (Zannetos, 1966, pp. 169 - 173, and 1975). This is not surprising given that vessels are normally operating 350 out of 365 days per year and cannot be used at higher speeds without severe cost penalties due to higher fuel consumption.

<sup>7</sup>The trend in the size of new tankers is expected to be reversed partly because more and more refineries are built in the oil-producing countries and the need will be for product rather than crude carriers. Because of the extensive economies of scale realized, the reversal in the trend will probably be mild.

B. Types of Market Transactions

As in the case of other rental transactions, tankers may be chartered for short or long periods of time, and with all or part of the services and utilities included in the rental. More specifically rentals for tankers can take the form of:

- (a) Spot charters, representing the cost of transporting a ton of oil between two specified ports. Spot charters are also known as voyage charters because they refer to one voyage and are expressed in terms of an index (World Scale), translatable into dollars or other currency per ton of oil delivered for the specified voyage.
- (b) Period Charters or Time Charters. These agreements extend over a specified time period. The charterer normally obtains the right to use the vessel for whatever route he/she wishes and for that reason the rental is expressed in terms of dollars per deadweight ton (DWT) of capacity per month. For time charters, the charterer assumes the financial responsibility for port charges and bunkers (fuel cost).
- (c) Consecutive Voyages. In between spot and time charters we find agreements which extend over a certain time period but for as many voyages on a specified route, as the charterer can fit. The consecutive voyage rates provide that all costs are assumed by the owner of the vessel and therefore are expressed like spot or voyage rates in terms of worldscale (WS).

(d) Bareboat Charters. As the name implies under these charter agreements, the charterer is provided with a bare boat which he/she equips with crew and assumes all the costs of operation. The rates for these charters, as in the case of period transactions, are expressed in terms of dollars per deadweight ton of capacity per month.

(e) Contracts of Affreightment. These represent agreements for the transportation of a certain amount of oil between two ports over an extended period of time. Unlike the other type of charters which refer to a specific vessel, and include a specific date for the commencement of the charter of the vessel, the contracts of affreightment allow the owners of the vessels to transport whatever quantity of oil they can, on whatever vessel and whenever the vessel owners find advantageous. These are not very common agreements and often provide for "minimax" limits for monthly deliveries, so as not to impose logistics problems on the refiners or buyers of the oil.

This paper will be concerned with spot charters, and more specifically, it will attempt to shed some light on the determinants of the structure of spot rates at any moment in time, given dynamic market conditions.

As we have pointed out above, spot rates represent the cost per ton of oil delivered between two ports. All the costs associated with the operation of the vessel, loading and unloading are borne by the tanker owner. If we now accept the proposition that the interactions in the

tanker markets approach those of perfect competition,<sup>8</sup> then one may conclude that there should be no structure for spot rates. In other words, the cost for delivering a ton of oil to a specific location at any moment in time, should be the same, some claim, no matter on what vessel the oil is carried.<sup>9</sup>

Those of us who have been following the tanker markets, have noticed at any moment in time, a definite negative relation between spot rates and vessel sizes.<sup>10</sup> Such observations have caused intellectual problems to, and raised doubts in the minds of, all those who accepted the premise that tanker markets are more or less perfect (efficient). And this, because they could not propose a plausible hypothesis which explains this paradox. Those, of course, who believe that the markets

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<sup>8</sup> Almost all of the spot charters are consummated through tanker brokers. This also includes the oil-company vessels that are relet. There are well organized trading centers (like stock exchanges) at several parts of the world, with the most important being London.

<sup>9</sup> As one of the most well known and colorful professionals in the field once stated in support of his position, "a spot rate is a spot rate is a spot rate."

<sup>10</sup> For an illustration, Gibson's report for the week of August 8, 1980, p. 1, lists the following transactions: For a 400,000 DWT tanker, the rate obtained was WS 16, for a 280,000 tonner WS 24-1/2 and for 250,000 tons WS 29.

for tankers are imperfect, see in the structure of tanker rates the empirical evidence supporting their position.

In our view, the structure of rates is not inconsistent with the hypothesis of perfect markets. On the contrary, the observed structure is the result of the efficiency of the workings of the tanker markets, as these tend to equalize returns and risks.

In 1959 in an attempt to explain the factors affecting the level and structure of time-charter rates in the short run, Zannetos (1959, Vol II, pp. 233 - 238) introduced the notions of risk of unemployment and risk of underemployment,<sup>11</sup> and provided empirical evidence to support these arguments. Later on, and still at a time when the economies of scale in tankers were not as pronounced as today,<sup>12</sup> Zannetos (1965) articulated a theory for long-term charter rates and elaborated further

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<sup>11</sup>The argument in essence is that expectations about future market conditions determine in the mind of owners and charterers, a priori, the risk of unemployment of the vessel which a time-charter agreement shifts from the owner to the charterer. In addition, the larger a vessel is, the greater the inflexibility and the concomitant probability that a vessel may be underutilized because of constraints of market size, refinery throughput capacity, storage availability, loading and unloading facilities, port depths and channel widths and depths. These last reasons introduce a risk of underemployment.

<sup>12</sup>As we have already mentioned prior to 1966, there were no vessels larger than 160,000 DWT. Today we have tankers of over 600,000 DWT.

on the impact of the risk of unemployment, the risk of underemployment, the long-run cost of operation, the time-charter duration, the spot-rate level, the transaction costs and the mortagageability of time charters on the time-charter rate for any tanker, at any moment in time. This theory was subsequently tested by Zannetos (1967), Somekh (1968), and Polemis (1976) with very good success.

Of the two dimensions of risk, unemployment and underemployment, only the risk of underemployment obviously, should affect the structure of spot rates.<sup>13</sup> And it is in here, in our estimation that we must look for an explanation of the structure of spot rates, under an efficient market hypothesis. Tanker owners build large vessels in order to achieve economies of scale, but at the same time create inflexibility for their vessels and run the risk of utilizing them partly loaded. It appears logical to expect that they will trade off some of the economies of scale they realize, in order to shift the risk of underemployment to the spot charterer. It is the empirical quantification of this risk, under various market conditions, that will occupy us mostly in this paper. To do this we will first develop a model describing the normal spot rate

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<sup>13</sup>The risk of unemployment is reflected in the level of spot rates as established by the general market conditions. In the case of the very large tankers operating in the spot market, their inflexibility may limit their employment opportunities to a greater extent than in the case of the smaller vessels. This dimension of risk we include in the risk of underemployment.

under various market conditions for the marginal vessel,<sup>14</sup> and attribute the differences from such a rate to the risk of underemployment.

One result of our efforts will be the determination of the proportion of the economies of scale accruing to tankers of large size which must be conceded to the charterers as compensation for decreased flexibility, under various market conditions. In the short run, the model that we develop will be of considerable assistance to decision makers, be these tanker owners or charterers, in that it will provide them with information on the normal rate for any particular vessel under the then prevailing market conditions.

### II. NECESSARY THEORETICAL NOTIONS

#### A. The Spot Market

The main purpose of the spot market for tankers is to satisfy unforeseen short-term increases in the aggregate demand for oil. It also satisfies predictable fluctuations, such as seasonal, in the demand facing the oil companies. If the dominant covariations in the needs of oil companies and other tankers users are negative, then the fluctuation in the total demand for transportation capacity is less than the sum of the absolute fluctuations in the needs of the individual users. Under such conditions, the total transportation capacity that is required to accommodate the requirements of the oil industry

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<sup>14</sup> In markets which are competitive, the equilibrium price is that which encourages the marginal capacity to enter and stay in the markets, in order to satisfy the quantity demanded at that price.

will be less, if the oil companies depend on the spot market to take care of the fluctuations around the expected value of their individual requirements, than it would be in the case where each firm were to try and provide for its maximum requirements. Tanker users have learned this lesson from experience and so did those entrepreneurs, the independent tanker owners, who saw in this an opportunity for an arbitrage.<sup>15</sup> As a result, organized tanker markets and professional tanker brokers evolved to satisfy the perceived needs. Tankers, therefore, are chartered and relet for single voyages, consecutive voyages, or for extended periods.

Although the spot market on the average provides employment for approximately only 15 percent of the world's total tonnage,<sup>16</sup> it is far more important than this percentage indicates because it influences expectations about the short-run and long-run

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<sup>15</sup> Of the total commercial world fleet of 317,444,282 DWT as of June 30, 1980, 190,805,222 or 60% belongs to private owners (independents) and 126,639,060 or 40% belongs to the oil companies. An additional capacity of 9,481,670 DWT consists of government and miscellaneous vessels but this is not used for commercial purposes. All these figures exclude vessels below 10,000 DWT. (J. I. Jacobs, Jan - June 1980 issue, Table 1)

<sup>16</sup> The oil companies have tried in the past to charter on a long term basis (normally in the form of five to seven years time-charters) for the major part of their needs. Empirically and over the tanker-market cycle, the total tonnage on time-charter fluctuates around 50% of the total needs of the oil industry.

market conditions. When the level of spot rates goes outside a "region of strict static relevance"<sup>17</sup> it significantly affects the level of time-charter rates. The latter rates once fixed, extend over the duration of the time charter.

Another long-term impact of the spot market is reflected in the shipbuilding backlog. It has been shown by Tinbergen (1934, in Klaasen Ed. 1959), Koopmans (1939) and Zannetos (1966; 1977), that orders for new vessels and spot rates are dynamically interdependent. Zannetos (1966) went a step further to link spot rates and price-elastic expectations,<sup>18</sup> and the latter to orders for new

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<sup>17</sup> For definition and discussion see Zannetos (1966 pp. 12-13, 17, 35, 64, 85.)

<sup>18</sup> The theory of consumer demand assumes that the dynamic expectation of consumers are price inelastic. If an increase of x% in the price of a good y occurs, it is assumed that future normal prices for y will rise permanently and proportionately less than x%. The rational consumer behavior therefore, would be to postpone purchase and for the producers to postpone input and accelerate output. The static effect of the price increase will result in lower purchases of y, because the present income of the consumers will be adversely affected and substitution will occur in favor of other goods whose prices did not increase as much. The opposite effect would result for price decreases. Hence, the negative slope of the demand curve. Zannetos has shown that transportation departments of oil companies operate under budget conditions similar to those of households and are affected by price-elastic expectations. As prices increase, therefore, the expectations of greater increases in the future encourage more and not fewer transactions, cause further price increases, and a positive demand slope. For more on this and the impact on market equilibria, see Zannetos (1966, pp. 7-29, 42-49, 77-80, 102-105).

vessels, placed with a lag of about six months from peak to peak. He also determined the conditions under which stable market equilibria may be observed in the tanker markets, and the dynamic process by which the level of spot rates is established. The work of the above authors has for reaching implications for the present discussion, in that it indicates that the spot rate may not only affect the future level and structure of rates but also sets things in motion which generate cyclical price behavior, within both the tanker-transportation and the tankship-building markets, without the necessity for cyclical demand.

Since it carries only a small percentage of the total tonnage, the spot market is very volatile. The supply schedule of tanker capacity is, short of a period long enough for shipbuilding, very inelastic beyond full capacity, but very elastic at its lower part because of the refusal rate of the various vessels as these become marginal at the various levels of demand. This change from elasticity to inelasticity occurs within less than two percentage points of total capacity, and indicates that a shift in the demand by as little as one percent around the critical area will be enough to create fortunes or disaster (Zannetos, 1966 pp. 169-173).

An increase of one percent in the total demand for tonnage is magnified in the spot market where it will comprise on the

average more than 6 percent of the capacity already operating there.<sup>19</sup> A slightly larger increase in demand may be enough to send spot rates to soaring heights and create a panic. For these reasons, the proportion of the tanker fleet operating in the spot market may serve as a barometer of the market conditions.

At any point in time a small proportion of the tanker fleet is out of the market, for maintenance and repairs. During periods of high rates, maintenance and repairs are expedited or even postponed wherever that is possible and, therefore, idle capacity is minimal. When rates are low, on the other hand, the maintenance period is normally extended. This and other withdrawals in readiness from the market may create a large idle capacity which is not laid up.<sup>20</sup> The proportion of the total capacity which is idle in readiness or for repairs and maintenance would, therefore, supplement the proportion of capacity operating in the spot market as an indicator of the level of freight rates.

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<sup>19</sup> Another consequence of price-elastic expectations is that more long-term transactions and for longer periods, are consummated during periods of high spot rates than during periods of low rates. This results in a very thin spot market when capacity is close to full utilization and in a large percentage of total capacity operating in the spot market under depressed market conditions. Shifts in demand, therefore, are disproportionately magnified in the spot market during periods of high versus low spot rates.

<sup>20</sup> During depressed market conditions many vessels are used for temporary storage (See Gibson, Septemeber 5, 1980)

### B. The Significance of the Marginal Vessel

The tanker market, as pointed out, is one of the few markets in which almost perfectly competitive conditions prevail. Ownership of tankers, even by anyone of the largest independent companies, is a small fraction of the total capacity. The mobility of capital, the ease of entry into the market, the absence of large administrative and financial optima which permit the vessel to operate as a firm and the absence of excessive artificial controls, all contribute to the perfectly competitive climate (Zannetos, 1966).

In a market which is governed by the uncontrolled interaction of supply and demand, the price at any moment in time is determined by the then available marginal capacity (Zannetos 1966; 1975). Similarly, freight rates must be at a level such that the marginal capacity will be able to earn its marginal cost, otherwise it will not enter the market. For the long run, this rate will be the applicable average full cost which includes a market-determined return on investment. In the short run, however, one may observe freight rates which are below the operating costs of the particular marginal vessels and yet the vessels may not refuse employment at those rates. The reason for this seemingly paradoxical behavior is that the alternatives to employment are (a) tie up, which is not costless <sup>21</sup>, or (b) scrappage which is

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<sup>21</sup>The costs associated with tie up include repatriation of crew, rental of a river basin, cove or other suitable space, a launch and a five-man crew for watch and minimum maintenance and utilities.

irreversible. If, therefore, the owners of the marginal vessel expect a recovery from the low rates, in a reasonable time, they will be better off to operate for awhile at rates which do not fully cover the out-of-pocket costs of their vessels.

Another seeming paradox emerges when one compares the weighted spot rate, time adjusted, which is applicable to a given size of a vessel over its life time, with the rate which will enable the owner to recover his investment and realize the necessary market return. Sometimes the former is lower than the latter, and the reason for this is that most vessels enter the spot market after a lengthy and profitable time charter.<sup>22</sup> In the case of most marginal vessels, by the time they reach that stage of their economic life they would have earned enough to liquidate the initial loan, recovered for the owner his investment, and produced a reasonable return. As a result, the owners of these vessels are willing to keep them operating, rather than default, as long as the rate is expected to cover their out-of-pocket costs and leave something for the owner. Those shipowners, who are risk prone and prefer to operate in the spot market exclusively will, of course, suffer if the rates are low when their new vessels are delivered from the shipyards. And if the depressed market conditions continue for any length of time, default of the loans and eventual bankruptcy may occur. In the recent years those who

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<sup>22</sup> If we include the company-owned vessels, 80-85% of the life of a tanker on the average, is on time charter or equivalent.

placed orders for new tankers as a result of the upsurge in spot rates to Worldscale 450 in October 1973, and did not secure time charters in advance, went through some very critical times and some of them did not survive.

When the spot rates are low and the then marginal vessels barely cover their operating costs, larger vessels because of economies of large size, are able to earn a very good return if these were to secure employment at that same rate. For this reason, and in order to provide an inducement to the charterers to shoulder the inflexibility of large size, a great percentage of the economies accruing to size are conceded to the charterers. Often the owners of large vessels in order to avoid unemployment accept engagements with "part cargo." This is a direct manifestation of the risk of underemployment. As Appendix I shows, over 8% of all available VLCC capacity, representing approximately 15 million DWT, was lost because large tankers traveled partly loaded during the last half of 1979.<sup>23</sup>

### III. THE MODELS

In order to develop a model which will enable us to determine the structure of rates at various points in time and under various market conditions, and further determine what part of the economies of scale accrue to the tanker owners versus the charterers, we must first develop a model to help us determine what will be the

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<sup>23</sup>In order to develop homogeneous data and measure the economies of scale accruing to the owner versus the charterer, the total revenue derived from a part cargo transaction is divided by the total available capacity of the respective tanker.

level of rates under different market conditions and marginal-vessel size. As we have already explained, the level of rates is determined by the applicable marginal vessel.

#### A. The Spot Rate of a Vessel at a Moment in Time

The model that we have developed consists of a non-linear combination of four variables which define  $S_t^n$ , the spot freight rate for a given size of vessel n at time t. The choice of explanatory variables has been made following an extensive study of the characteristics of the tanker markets and the formation of short-term rates as described by Zannetos (1966). A brief outline of the underlying theory has been provided in the previous section and for a thorough rendition and more elaboration on terms and methods of measurements the reader is advised to consult the aforementioned references.

The variables used in the model which we will test are defined as follows:

- (a)  $R_t^m$  : the operating costs of the marginal vessel m at time t.
- (b)  $X_1$  : percent of working fleet operating in the spot market.
- (c)  $X_2$  : the ratio of the capacity of a given vessel to that of the marginal vessel at time t, expressed as a percentage.
- (d)  $X_3$  : the tanker tonnage laid up as a proportion (to the nearest thousand DWT) of the total tanker fleet tonnage at time t.

The spot rate  $S_t^n$  for a given size n of a vessel at time t, is then defined as:

$$S_t^n = K \cdot R_t^m \cdot X_1^a \cdot X_2^b \cdot X_3^c \quad (1)$$

where K is a constant, and a, b, and c are exponents.

This model was applied to the actual spot market transactions reported between September 1971 and December 1976.<sup>24</sup> This period contains one complete cycle of spot rates. In order to detect possible changes in the relative significance of the independent variables, the model was tested under various market conditions over the rate cycle. Existing theory tells us that such changes should be observed. (Zannetos 1966; 1975; 1977).

The transactions used were those reported monthly by H. P. Drewry (3) for the Persian Gulf - U.K./ Continent route. The latter route was chosen because more oil flows between these two geographic areas than over any other single route. Besides, the existence of proper ancillary facilities at most loading and unloading ports on that route make possible the chartering of vessels of all sizes, which is necessary for analyzing the structure of rates. Information with regard to the proportion of the world's tanker fleet operating in the spot market and the proportion of the fleet laid up for two months or more, was obtained from the same source.

The definition of what constitutes a marginal vessel is fundamental not only to the understanding of the model but also to its application. The marginal class of vessels cannot refer to the smallest vessels operating in the markets because these vessels are mostly used for special purposes, such as for transporting oil to isolated harbors which are not equipped to handle larger vessels. As a result, the

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<sup>24</sup>We chose the period so that it includes at least one full cycle from trough to trough.

definition of "marginal capacity", for spot-rate purposes, must be based on the smallest size class operating in the major crude-trade routes in normal periods. Furthermore, the marginal size class has to be a substantial proportion (between 5 and 10 percent) of the capacity operating in the spot market, otherwise it will not be influential in setting the level of rates.<sup>25</sup>

Starting with the above definition of the marginal size class, the size distribution of tankers operating in the Persian Gulf - U.K./Continent route was examined, to determine what size classes constituted a significant proportion of total available capacity at the various points in time.<sup>26</sup> The analysis showed that the marginal-size class for the last four months of 1971 was in the 45,000 - 54,999 DWT range, that of 1972 and 1973 was in the 55,000 - 64,999 DWT range for 1974 and 1975 was in the 75,000 - 99,999 DWT range and for 1976 the marginal class was in the 100,000 - 149,999 DWT range. The size of the marginal vessel in each case was taken as the mid-point of the marginal class.

Information on operating costs of tankers is scarce. Attempts to obtain recent cost figures have not been successful because tanker operators consider their cost data confidential and hesitate to release

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<sup>25</sup> There is no fool-proof scientific way that one may apply to determine the exact percentage. We use 5 to 10% of capacity operating in the spot market because, as already explained, the short-term supply schedule changes from elastic to inelastic within two percentage points of total capacity.

<sup>26</sup> For the size distribution of all tankers at various points in time, see the various semi-annual issues of World Tanker Fleet Review of John I. Jacobs Company Ltd.

them to outsiders. For the purposes of the present study the cost data used were obtained from Polemis (7), and are based on actual figures and forecasts provided by respectable tanker operators, tanker brokers and the U. S. Maritime Administration.<sup>11</sup> Table 1 shows the operating costs of the marginal vessel during the period under consideration.

Table 1. Operating Costs of the Marginal Vessel

Year	DWT	Out of Pocket Costs		Fuel Costs \$/DWT/ Trip	Port Charges \$/DWT/ Trip	Total Operating Costs \$/DWT/Trip
		\$/DWT Month	\$/DWT/ Trip			
1971	50,000	1.2359	2.7515	1.7240	0.1358	4.6113
1972	60,000	1.1808	2.6289	1.5913	0.1247	4.3449
1973	60,000	1.3346	2.9713	1.9203	0.1247	5.0163
1974	87,000	1.1555	2.5725	4.2340	0.1043	6.9108
1975	87,000	1.4858	3.3079	4.4216	0.1043	7.8338
1976	125,000	1.3376	2.9780	3.5959	0.0905	6.6644

The out of pocket costs consist of:

- (a) Crew wages and salaries
- (b) Subsistence costs and supplies
- (c) Insurance
- (d) Maintenance and repairs, and
- (e) Miscellaneous costs

All these costs, together with fuel costs and port charges are paid by the owner of the vessel when it operates in the spot market.

#### B. Application of the Model of Spot Rates

The model we have just described was applied and its coefficients were evaluated using the actual single voyage fixtures, 1630 in all, from September 1971 to December 1976.

Several versions of the general model were tested, but one gave consistently better results than the rest. This version is a logarithmic regression equation with the ratio of the spot rate of the  $n^{\text{th}}$  vessel divided by the operating costs of the marginal vessel, as the dependent variable, and the percent of the working fleet<sup>27</sup> operating in the spot market ( $X_1$ ), the size ratio of the chartered vessel to that of the marginal vessel ( $X_2$ ) and the proportion of the total tanker tonnage laid up ( $X_3$ ) as the explanatory variables.

In applying the model, certain problems of positive serial correlation were encountered. This is believed to be the result of many factors, the most important of which are:

(a) The length of the time period over which the marginal vessel was kept constant. In the present application, the size of the marginal vessel was chosen to represent the market conditions over a calendar year after examining the spot transactions that have taken place during that year. In periods of rapidly increasing or rapidly decreasing rates the size of the marginal vessel is expected to change many times within a year. By taking an average for the year, we tend to overestimate the size when rates are increasing and underestimate it when rates are decreasing. Because of this averaging we also expect our model to underestimate the rates at the peak of the cycle and overestimate these at the trough.<sup>28</sup> An obvious refinement will be achieved by determining the

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<sup>27</sup> The working fleet includes all available commercial tonnage (i.e. excludes government-owned tankers) minus special-purpose vessels and tankers idle for thirty or more days for repairs or lay up.

<sup>28</sup> For reasons analyzed by Zannetos (1966, Chapter 8), the range of spot rates from "normal" to peak is far greater than the range from normal to trough. Our model as a result is expected, because of averaging, to perform worse at the peak of the cycle.

marginal vessel from monthly or even weekly transactions, especially during periods of highly fluctuating rates and obtaining the actual operating costs of such vessels.

(b) The time period between consecutive measurements of the proportion of the tanker fleet operating in the spot market and the proportion of the tanker fleet which is laid up. These parameters are revised monthly. However, in many cases, often near the critical range, these proportions may change 2 or 3 percentage points from one month to the next. Since even a one percentage movement, up or down, in the critical range of the proportion of the fleet operating in the spot market is enough to bring fortune or disaster to shipowners, shortening the period between consecutive measurements of these parameters is likely to bring about substantial improvement in the performance of the model. This task, however, is expected to be very difficult and laborious in the absence of published weekly statistics.<sup>29</sup>

(c) The price-elastic expectations and the induced interperiod substitutions which prevail in the tanker markets during periods of abnormally high or abnormally low rates (Zannetos 1966, 1975, 1977).<sup>30</sup>

In order to reduce the serial correlation, the regressions were run using the Cochrane - Orcutt iterative technique. (See D. Cochrane and G. H. Orcutt 1949). This approach suggests that an initial estimate

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<sup>29</sup> There is also another problem in that often these statistics are not reported exactly when they happen.

<sup>30</sup> Price-elastic expectations and induced Morkovian properties in the movement of rates as observed by Zannetos (1966, p. 199 - 201), can easily introduce positive serial correlation.

of  $p$ , the first order serial coefficient, be made using ordinary least squares regression. Then:

- (i) all the data are transformed by  $p$  (e.g.  $X_t - p X_{t-1}$ )
- (ii) a regression is run on the transformed data
- (iii) the regression coefficients are multiplied into the original dependent variables to recalculate the serially correlated errors.
- (iv) a new estimate of  $p$  is formed, and a new iteration begins.
- (v) when  $p$  changes by less than 0.005 from one iteration to the next, the iteration terminates and a regression output is produced.

The results of the statistical analysis are shown in Table 2.

When the Cochrane-Orcutt technique is used, the Durbin-Watson statistic and the coefficient of determination ( $R^2$ ) are calculated from the residuals of the regression on the transformed variables. In all regression equations the dependent variable is the natural logarithm of the ratio of the spot rate to the operating costs of the marginal vessel, at time  $t$ , expressed as a percentage, i.e.

$$Y = (S_t^n / R_t^m) \times 100\% \quad (2)$$

Part A of Table 2 shows the results of the application of the model on the data of the entire period under consideration. Despite the inherent volatility of spot freight rates and the relative lack of refinement in the construction of the data base, two aspects on which we commented previously, the fit is reasonably good. All the explanatory variables are highly significant and their coefficients have the sign predicted by the theory. The

spot rate for a vessel in question decreases with an increase in (a) the percentage of the tanker fleet operating in the spot market, (b) the size of the vessel relative to the marginal vessel, and (c) the percentage of the fleet which is laid up. Of the three explanatory variables  $X_1$  (the percentage of fleet operating in the spot market) seems to be the most important.

Practically no collinearity exists between the independent variables. A more serious problem is, evidently, the existence of positive serial correlation, shown by the Durbin-Watson (DW) statistic. The Cochrane-Orcutt technique corrects that to a great extent as seen in the regression of the transformed data. The general relationships observed in the ordinary least squares regression are preserved and become even stronger, with R increasing from .828 to .955.

Table 2 Results of the Regression Analysis

A. Regression with 1630 observations from September 1971 to December 1976.

(a) Ordinary Least Squares

$$\ln(Y) = 10.4781 - 1.1167 \ln(X_1) - 0.2778 \ln(X_2) - 0.3887 \ln(X_3)$$

t-statistics (79.493) (-34.209) (-13.533) (-36.587)  
 $R = 0.828 \quad R^2 = 0.6858 \quad DW = 0.3042$

(b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 9.4755 - 0.7762 \ln(X_1) - 0.2487 \ln(X_2) - 0.4037 \ln(X_3)$$

t-statistics (34.122) (-7.775) (-25.991) (10.697)  
 $R = 0.955 \quad R^2 = 0.9127 \quad DW = 2.6146 \quad p = 0.86$

B. Regression with 1122 observations from September 1971 to December 1972 and from December 1973 to December 1976.

(a) Ordinary Least Squares

$$\ln(Y) = 8.8248 - 0.6225 \ln(X_1) - 0.3512 \ln(X_2) - 0.2404 \ln(X_3)$$

t-statistics (76.269) (-22.744) (-20.033) (-27.755)  
 $R = 0.789 \quad R^2 = 0.6223 \quad DW = 0.5866$

(b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 8.4822 - 0.5614 \ln(X_1) - 0.3152 \ln(X_2) - 0.2420 \ln(X_3)$$

t-statistics (41.942) (-8.865) (-27.789) (-11.509)  
 $R = 0.901 \quad R^2 = 0.8127 \quad DW = 2.4826 \quad p = 0.713$

C. Regression with 508 observations from January 1973 to November 1973.

(a) Ordinary Least Squares

$$\ln(Y) = 6.8176 - 0.8096 \ln(X_1) - 0.1744 \ln(X_2) + 0.8671 \ln(X_3)$$

t-statistics (17.527) (-8.994) (-5.958) (9.119)  
 $R = 0.586 \quad R^2 = 0.3436 \quad DW = 0.4316$

(b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 7.0466 - 0.7687 \ln(X_1) - 0.1031 \ln(X_2) + 0.5540 \ln(X_3)$$

t-statistics (8.458) (-3.356) (-6.115) (2.398)  
 $R = 0.870 \quad R^2 = 0.7567 \quad DW = 2.4024 \quad p = 0.800$

## D. Regression with 168 observations during 1975

## (a) Ordinary Least Squares

$$\ln(Y) = 11.3705 - 1.0191 \ln(X_1) - 0.5582 \ln(X_2) - 0.3813 \ln(X_3)$$

t-statistics (11.547) (-5.339) (-15.768) (-3.930)

$$R = 0.786 \quad R^2 = 0.6179 \quad DW = 1.300$$

## (b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 11.3157 - 1.0038 \ln(X_1) - 0.5442 \ln(X_2) - 0.3941 \ln(X_3)$$

t-statistics (8.394) (-3.790) (-16.500) (-2.872)

$$R = 0.815 \quad R^2 = 0.6648 \quad DW = 2.138 \quad p = 0.352$$

## E. Regression with 235 observations from June 1973 to November 1973

## (a) Ordinary Least Squares

$$\ln(Y) = 5.5873 - 0.3664 \ln(X_1) - 0.2057 \ln(X_2) + 1.0869 \ln(X_3)$$

t-statistics (10.3223) (-3.631) (-4.973) (6.630)

$$R = 0.537 \quad R^2 = 0.2881 \quad DW = 0.691$$

## (b) Cochrane-Orcutt Iterative Technique

$$\ln(Y) = 6.1224 - 0.4422 \ln(X_1) - 0.0968 \ln(X_2) + 0.6878 \ln(X_3)$$

t-statistics (5.844) (-1.956) (-3.153) (2.076)

$$R = 0.783 \quad R^2 = 0.6128 \quad DW = 2.380 \quad p = 0.700$$

The results of the first attempt to test the model under various market conditions are given in part B of Table 2. The two periods considered here are characterized by low rates, generally less than Worldscale 80. Comparing these results with those for the entire period, we observe the increased significance of size under conditions of low rates. This is reflected in the magnitude of the coefficient of  $\ln(X_2)$  in the regression equation which is equal to -0.3152 for the period of low rates while it equals -0.2487 for the entire cycle. We also notice the decreased significance of  $X_1$  and  $X_3$ . As is well known, given the form of the model we are using, these coefficients represent the elasticity of the dependent variable with respect to the explanatory variables.

Part C of Table 2 represents the results of the regression for a period of relatively high rates. During this period spot rates were generally higher than Worldscale 80. A significant difference between these results

and those presented earlier for the period of low rates, is the existence of a positive correlation between the proportion of the fleet laid up and the level of spot rates. This reversal of sign in the relationship is one of the asymmetries which theoretically is to be expected, and is associated with the particular cause and effect relationship that exists between these two variables. The explanation is that, during low rates, the proportion of the fleet laid up is an effect of the depressed rates. Small vessels are withdrawn from the market, maintenance and repairs are protracted, waiting for a recovery, and in order to avoid excessive losses due to permanent lay up or idleness in readiness. This gives rise to the negative correlation. When rates fall, as a result of a decrease in the demand for oil or an increase in the tanker fleet capacity, the proportion of the total tonnage laid up increases. As rates increase and the utilization of the fleet approaches full capacity, more and more small, inefficient and old ships enter the market, all ships sail at full steam and repairs and maintenance are postponed. Up to this point the negative relationship still holds. The reversal of the relationship and the new role of  $X_3$  as a cause of higher rates appears a few months later. Because of the increased wear due to the higher speed, the postponed, hasty or inadequate maintenance, the use of older tankers and the possible increase in the number of accidents, due to denser traffic, some ships withdraw from the market for repairs. Such withdrawals of capacity at the inelastic part of the supply schedule cause the rates to go up even further. Hence the positive correlation.

The regression equation for this period, though all the coefficients are highly significant, does not explain the movement of rates as well as it does for the entire period or for periods of low rates. The value of the coefficient of determination ( $R^2$ ) is only half that for the entire period,

when ordinary least squares are used and still considerably lower when the Cochrane-Orcutt technique is used. An important result, however, can be observed by comparing the regression equation of part C of Table 2 with those of part B. The elasticity of Y with respect to  $X_2$  is much smaller when the level of freight rates is high than at low rates. During periods of high rates, there is scarcity of tonnage and, therefore, the risks for unemployment or underemployment do not exist, especially in the short run. The owners of large vessels do not have to concede much to encourage the charterers and, as a result, enjoy the economies of scale accruing to their vessels almost to the full extent. These findings give support to the theoretical arguments.

The last two parts (D and E) of Table 2 are intended to give a closer look at the differences in the process of rate formation between periods of high and low rates. Table 2-D shows the results for 1975, a period of very depressed spot rates, generally below Worldscale 50. On the other hand, Table 2-E shows the results for a period of very high spot rates, higher than Worldscale 150. Qualitatively, the results are consistent with those of parts B and C respectively. As for the quantitative measurements, the asymmetric behavior of  $X_3$  is accentuated and the difference in the elasticity of Y with respect to  $X_2$  between periods of low and high rates, is further reinforced.

#### C. Estimation of Economies of Scale

The quantification of the effect of vessel size on spot rates, under different market conditions, facilitates the estimation of the proportion of the economies of scale which are enjoyed by the owners of large vessels and that which is conceded to the charterers. These

rate concessions determine the structure of spot rates around a level determined by the relevant costs (depending on market conditions) of the then marginal transportation capacity. Since the proportions of the economies of scale conceded do not remain constant but depend on the general market climate, we can only estimate them during discrete time intervals, under more-or-less steady conditions. Also, as we have already explained, in order that these numbers be meaningful they should represent the economies of scale relative to the marginal vessel operating in the market during the period under consideration.<sup>31</sup>

Zannetos (1966, pp. 196 - 199) explained theoretically and provided empirical support to his theoretical arguments that the most likely states or regions of stable equilibria of spot rates are at: (1) rates far above the long-run economic cost of the marginal vessel and (2) rates at/or below the out-of-pocket cost of the marginal vessel. In other words the spot-rate equilibria are to be found in regions either excessively above those dictated by the long-run supply schedule of the industry or below. For this reason, we will estimate the economies of scale and the proportions, thereof, enjoyed by the owner and the charterer during discrete periods at each of these two states. Another period, however, which is thought to yield results representative of the longer term will also be considered. But first we will produce a workable definition of the economies of scale and the relative proportions of such that remain with the owners.

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<sup>31</sup>For a curve showing the relationship between the long-run economic costs of tankers of various sizes, see Appendix II-1.

In order to define the economies of scale and calculate the relevant proportions we must first identify the relevant costs which should be used. As it has been explained, the basis of the rate level, especially during periods of low rates, is the marginal cost of the marginal ship. For a tanker operator who is in the spot market, whether after a long period on time charter or not, the main consideration in the short run is the coverage of the operating costs of his vessel. For this reason, in the formulation only operating costs will be considered.

We define the total economies of scale accruing to a vessel at any point in time as the difference between the contribution margin of the given vessel and that of the marginal vessel, assuming that both realize the same spot rate, i.e. the difference in the relevant costs. If one were to use a "per ton of capacity" measure, the economies of scale for a given vessel  $n$  will be the difference between the short-run operating costs per ton of capacity of the marginal vessel  $m$  and those of vessel  $n$ . For minor computational reasons and because of the estimation of other variables in the formulation, however, we found it easier to work with total contribution margins.

Although most vessels enter the spot market after the major part of the initial investment has been paid back, in the general formulation we must define a common factor on the basis of which future net cash inflows of vessels of different sizes may be made directly comparable, and also take care of the fact that larger vessels achieve a slightly

better payload per DWT than smaller vessels.<sup>32</sup> This factor may be the level of the initial investment. Since, generally, the shipbuilding cost of a vessel of size  $2n$  is less than the cost of two vessels of size  $n$  each, we define a variable, which we will call "marginal vessel equivalent",  $E_n$ , such that,

$$E_n = \frac{\text{Total shipbuilding cost of vessel, size } n, \text{ at time } t}{\text{Total shipbuilding cost of the marginal vessel at time } t}$$

It should be noted that the size of the marginal ship is determined with respect to a reference period and not the period when the order was placed. For the purposes of the present analysis it is assumed that ships were ordered two to four years<sup>33</sup> before the period when their operating costs and revenues are considered. This may appear to contradict our previous assertion that there is normally a long interval between the building of a vessel and its entry into the spot market. Since, however, both the total economies of scale and the proportion of these that is enjoyed by the owner of a vessel of size  $n$ , are not constant but vary with time, our analysis aims at introducing and illustrating a method of short-run measurement rather than calculating a

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<sup>32</sup>A definition based on differential cash inflows is very appealing. Given, however, not only the stage of repayment of the initial loan but also the variety of financial arrangements that owners may use, we find it non-generalizable and impractical.

<sup>33</sup>This represents the range of the shipbuilding cycle. When the backlog is low vessels may be constructed in two years or less, but when the yards are congested it takes four or more years.

"universal constant". Furthermore, the relationship between shipbuilding costs of large and small vessels does not remain constant over the tanker-rate cycle, and as a result the "most recent" experience of tanker owners tends to influence their decisions much more than the distant past.<sup>34</sup> It must be stressed again that the factor  $E_n$  is not intended to account for the "recovery of the initial investment", which is a sunk cost. It is used as a surrogate for equating the short-run opportunity costs of the respective investments and for those dimensions of short-run efficiency of the large vessels (such as carrying capacity) which are not reflected in simple DWT ratios or in absolute operating costs.

Using the notation of section III and additional parameters defined below we will now develop formulae for the total economies of scale and calculate the proportions of these enjoyed by the owners and the charterers. Let,

$(DWT)_n$  = capacity in dead-weight-tons of the  $n^{\text{th}}$  vessel

$(DWT)_m$  = capacity in dead-weight-tons of the marginal vessel for the period under consideration

$R_t^n$  = the operating costs of a vessel, size  $n$ , at time  $t$  per DWT

$S_t^m$  = the spot rate per ton of oil delivered for the marginal vessel at time  $t$ , estimated by the regression equation of  $Y$  against  $X_1$ ,  $X_2$ , and  $X_3$ , as per Equation (1). We assume here that carrying capacity is approximated by DWT.

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<sup>34</sup>As we have already stated, most of the critical decisions are made by the owners from the point of view of the vessel as a firm.

A fixed level of investment,  $I$ , for a given base period, would enable a shipowner to purchase either one vessel of capacity  $(DWT)_n$  or  $E_n$  smaller vessels of capacity  $(DWT)_m$ . These two alternatives will generate cash flows, when operating in the spot market during some future period, as follows:

$$\text{Contribution margin (C.M.) of the } n^{\text{th}} \text{ vessel } (C.M.)_n = (S_t^n - R_t^n) (DWT)_n \quad (3)$$

$$E_n \text{ marginal vessel } (C.M.)_m = E_n (S_t^m - R_t^m) (DWT)_m \quad (4)$$

Their difference is

$$\begin{aligned} \Delta (C.M.) &= (C.M.)_n - E_n (C.M.)_m \\ &= (S_t^n - R_t^n) (DWT)_n - E_n (S_t^m - R_t^m) (DWT)_m \end{aligned} \quad (5)$$

The contribution margin of the  $n^{\text{th}}$  vessel if it realizes the same spot rate as the marginal vessel during the same period is

$$(C.M.)_{n/m} = (S_t^m - R_t^n) (DWT)_n \quad (6)$$

The total realizable economies of scale for the  $n^{\text{th}}$  vessel during the period under consideration is then:

$$\begin{aligned} (E.S.) &= (C.M.)_{n/m} - E_n (C.M.)_m \\ &= (S_t^m - R_t^n) (DWT)_n - E_n (S_t^m - R_t^m) (DWT)_m \end{aligned} \quad (7)$$

$$= S_t^m [ (DWT)_n - E_n (DWT)_m ] + R_t^m E_n (DWT)_m - R_t^n (DWT)_n \quad (8)$$

The proportion of these economies of scale which is enjoyed by the owner of the  $n^{\text{th}}$  vessel is:

$$\begin{aligned} (E.S.)_o &= \frac{\Delta(C.M.)}{(E.S.)} \\ &= \frac{(S_t^n - R_t^n) (DWT)_n - E_n (S_t^m - R_t^m) (DWT)_m}{(S_t^m - R_t^n) (DWT)_n - E_n (S_t^m - R_t^m) (DWT)_m} \end{aligned} \quad (9)$$

Since by our previous definition

$$X_2 = \frac{(DWT)_n}{(DWT)_m} \times 100\%$$

the above formula becomes

$$(E.S.)_o = \frac{(S_t^n - R_t^n) X_2 - 100 E_n (S_t^m - R_t^m)}{(S_t^m - R_t^n) X_2 - 100 E_n (S_t^m - R_t^m)} \quad (10)$$

It follows that the proportion of the economies of scale which is conceded to the charterer is equal to:

$$(E.S.)_c = 1 - (E.S.)_o$$

#### D. Economies of Scale Under High, Low and Normal Spot Rates

The economies of scale for ships of various sizes during August 1973, October 1974 and May 1975 were calculated using the formulae of Section III-C.

During August 1973 spot freight rates had already risen considerably and were still rising. Their level was in the range between WS 250 and WS 300 using the 1973 Worldscale. Later on it climbed to WS 450. Using shipbuilding costs for 1971, as estimated by Polemis (7), and a marginal vessel size of 60,000 DWT, the proportion of the economies of scale enjoyed by the owners of vessels of various sizes was calculated. The findings were plotted and shown in Figure 1. It can be seen that the shape of the plot is a slightly downward sloping straight line. After an initial drop in the proportion of economies of size remaining with the vessel owner, the curve levels off and does not drop below 67% even for ULCCs. The reason for this is that the

proportion of economies of scale conceded to the charterer accounts only for the loss of flexibility on his part, because during this period of very high rates and tonnage scarcity the risks for unemployment and underemployment did not exist. It should be noted that the estimation of spot rates for this period was made using the regression equation of part E(b) of Table 2.

In a similar fashion, using the Cochrane-Orcutt regression equation of part D, table 2, and equation (10) the results shown in Figure 2 were obtained for May 1975. The two curves were obtained using shipbuilding costs of two different periods in the past. The month of May 1975 is of particular importance because it is characterized by very depressed spot rates, the lowest that have ever been encountered in the spot market up to that time. In fact, during this period, ships of all sizes were operating at a loss, some of them not even covering the cost of fuel. The lower limit of spot rates during such a period is determined by the marginal costs of the marginal ship less the layup costs and the expected reactivation costs, spread over the expected layup period. In this case the economies of scale represent the reduction in losses relative to the marginal ship if the given vessel realized the spot rate of the marginal ship. The extent to which this loss reduction is realized by the owner, represents the proportion of the economies of scale that he enjoys, according to our definition. Shipbuilding costs appear to be very significant in the estimation of  $(E.S.)_o$  during this period. Since both the level and structure of shipbuilding costs change with time, it is interesting to note that a correct decision taken at some past period, with reference to some future market situation, may prove to be wrong.

for someone else who made the same decision at a different period, although the reference market conditions may remain the same.

Another important characteristic shown in Figure 2 is the rapidly decreasing proportion of economies of scale enjoyed by the owner of the vessel. The cause of this is as Equation (10) shows, the particular choice of the marginal vessel. In our case, we have chosen for illustration purposes a vessel of 60,000 DWT. The shape of the curve appears to be independent of the year when the shipbuilding order is assumed to have been placed. The substantial concessions that the owner must make to the charterer, which mostly occur for vessels 2-1/2 times as large as the marginal vessel, reflect the increased risk of unemployment and under-employment, on top of the decreased flexibility, that a charterer assumes when chartering a large vessel. The levelling off of the curve above a capacity of approximately 220,000 DWT, for 1975, reflects the fact that the economies of scale realized by the charterer beyond that size exactly match the additional risk and costs of inflexibility involved.

Figure 3 shows the proportion of the economies of scale enjoyed by the owners of vessels of various sizes under the market conditions prevailing in October 1974. During this period 24 percent of the working fleet was operating in the spot market and 1.3 percent was laid-up. The average spot rate realized by the marginal vessel at that time, estimated by the regression equation of Part A (b), Table 2, was approximately 25 percent above its operating costs. This situation is considered representative of the "normal" long-term market situation where the marginal vessel earns its marginal cost plus a market determined return on investment.

The shape of the graph is very similar to that of Figure 2 showing that even during periods of low, but not depressed, rates, the owner, according to our model, concedes an increasing proportion of the economies of scale in order to induce the charterers to hire a larger vessel. The same levelling-off of the graph, however, is again observed, for vessels above the 220,000 DWT. The time, when the investment decision was made, causes an almost vertical shift of the curve, reflecting the different structures of shipbuilding costs during different periods.

The analysis so far may have created the impression that, the owners of very large vessels may realize lower returns on their investment, because they retain a smaller part of the economies of scale which accrue to their vessels than do the owners of vessels of less than twice the size of the marginal vessel. This, however, is not the case, because the investment required per ton of carrying capacity for vessels of different sizes varies. A simple calculation can verify that although the owners of very large vessels concede a large amount of the economies of scale to the charterers, what they retain enables them to realize a higher return on investment, than if they had invested in smaller vessels. Taking for illustration the market conditions of October 1974 and the shipbuilding costs of 1971 as a representative scenario, we find that the initial investment, the estimated operating costs, the spot rate and the contribution margin, for a single trip, for a 100,000 DWT and a 300,000 DWT vessel respectively are as follows:

	<u>100,000 DWT</u>	<u>300,000 DWT</u>
1. Initial Investment, \$ m	17.100	36.083
2. Operating Cost, \$/DWT/trip	6.396	4.138
3. Spot Rate, \$/DWT/trip	8.330	6.330
4. Contribution Margin \$/trip	203,400	657,600

If we now obtain the ratio of contribution margin to initial investment, we find that comparable figures are 1.2 for the 100,000 DWT vessel and 1.8 for the 300,000 DWT vessel.

It can be seen, therefore, that although the owner of the 300,000 DWT vessel enjoys only 25 percent of the total economies of scale, compared with 55 percent for the owner of the 100,000 DWT vessel, the former achieves a higher return on his investment. Furthermore, and as we have already intimated, the relative payload of the 300,000 DWT vessel is greater than three times that of the 100,000 DWT tanker, further enhancing the return on investment of the larger vessel.

These calculations have been carried out on the assumption that the vessels operate in the spot market. Overheads, inspection costs, taxes, and the risk premium for unemployment were not considered. It can be shown that the larger vessels yield a higher return on the owners' investment in the long run, than the smaller vessels, because the indirect costs do not increase proportionately with size (Zannetos, 1967). Such a long run analysis of return on investment, however, is beyond the scope of the present paper.

In order to test how well the proposed model explains the prevailing spot rates, we present in Figure 4 a comparison between actual and estimated rates. The actual rates were obtained from Drewry (3) and represent the relevant rates for vessels of 100,000 to 174,999 DWT. Our estimates are obtained from the regression equation of Part 2 (b) of Table 2 for periods of high rates, and regression equation of Part 3 (b) of Table 2 for low rates. In both cases of estimated spot rates a vessel of 150,000 DWT is used.

As can be seen in Figure 4 the prediction of the model is quite respectable. Because Drewry's data are monthly averages of the transactions recorded and refer to a range of sizes (100,000 DWT to 174,999 DWT), the predictive power of our model has been adversely affected. Had we used actual data for 150,000 DWT vessels, we believe that the prediction would have been even better.

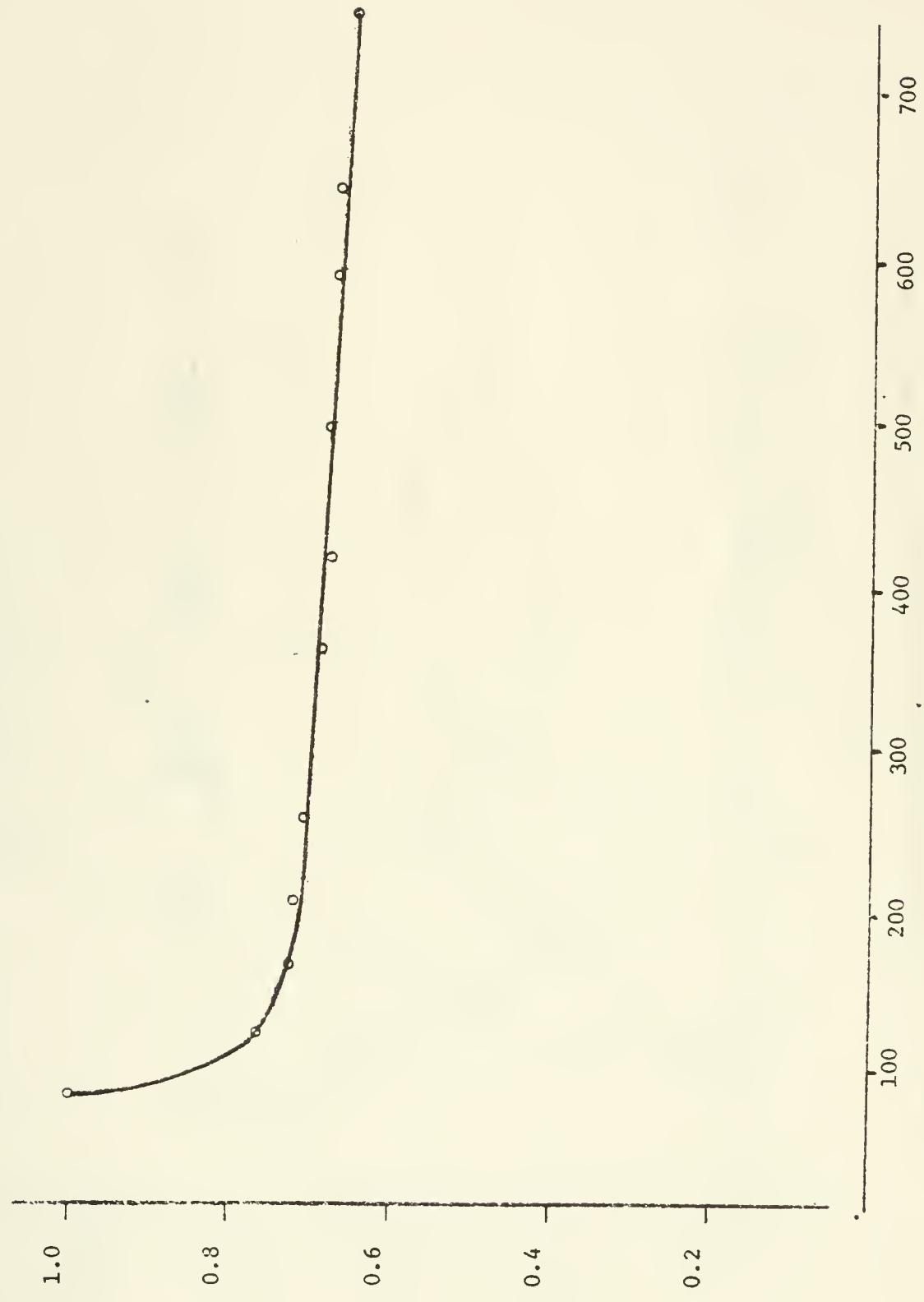
#### IV. CONCLUSIONS

The statistical model, despite certain inefficiencies arising from either unrefined or inadequate data, gave us very encouraging results in measuring the relative importance of the various quantifiable market characteristics in the formation of single-voyage freight rates.

The model enabled us to isolate the effect of vessel size on the formation of spot rates under various market conditions. This datum is of particular importance to oil exporters and shipowners alike. The results of our empirical investigation, are in complete agreement with theoretical predictions. Thus, during periods of capacity shortage and high freight rates, the owners enjoy a substantial proportion of the economies of scale that their large vessels realize, but during periods of excess capacity and low freight rates they have to concede most of these economies to the charterers, as compensation for the decreased flexibility and the increased risk of underemployment the charterers assume. However, the economies of scale are so large that, despite the substantial concessions to the charterers, the owners earn a higher return on their investment in large vessels than if they had invested in small ones. Even during periods of extremely depressed rates the owners of large vessels lose less per unit of capacity than the owners of small vessels.

FIGURE 1

PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: AUGUST 1973



RELATIVE SIZE AS A PERCENTAGE OF THE MARGINAL VESSEL

FIGURE 2 PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: MAY 1975

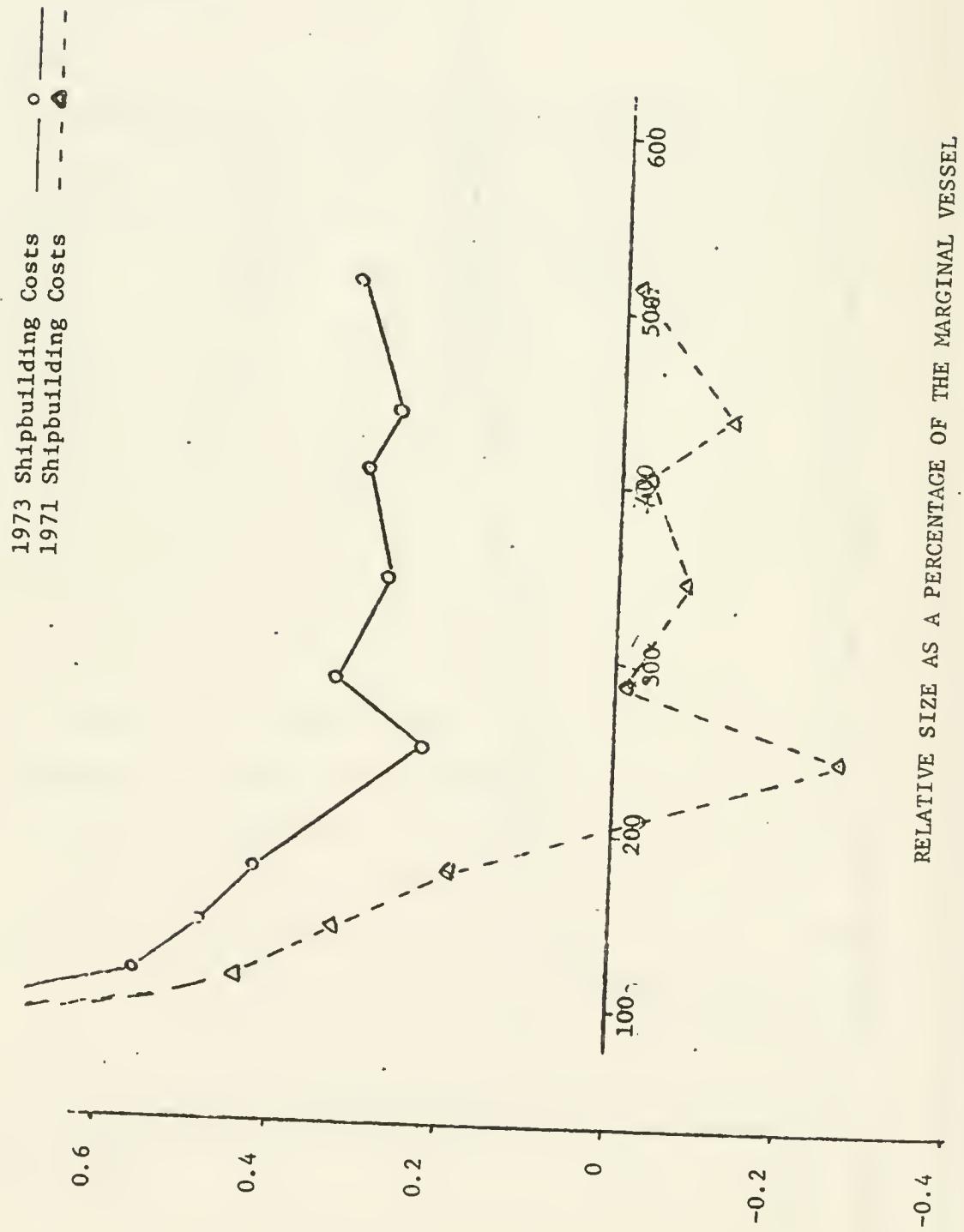


FIGURE 3 PROPORTION OF ECONOMIES OF SCALE ENJOYED BY OWNER: OCTOBER 1974

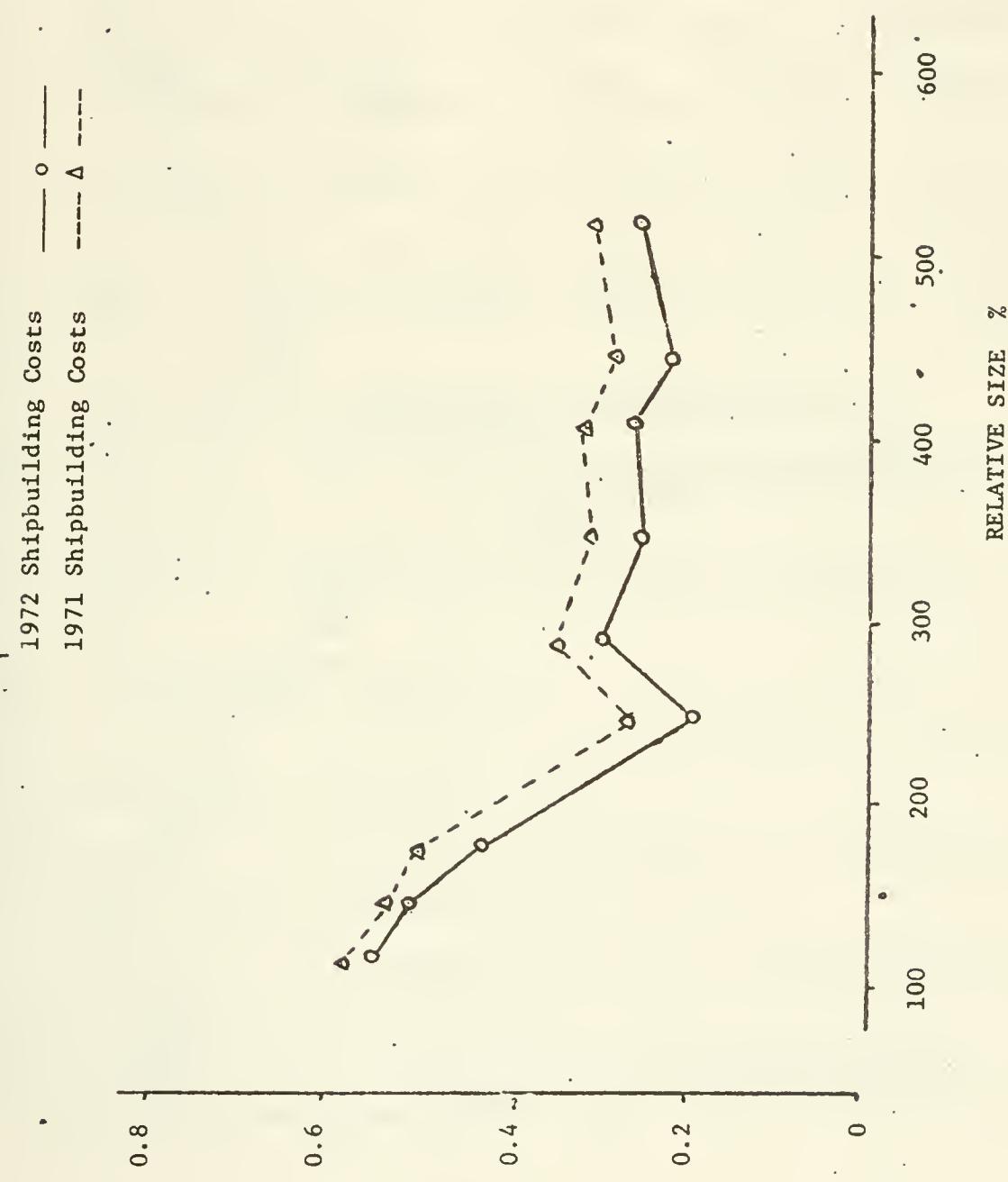
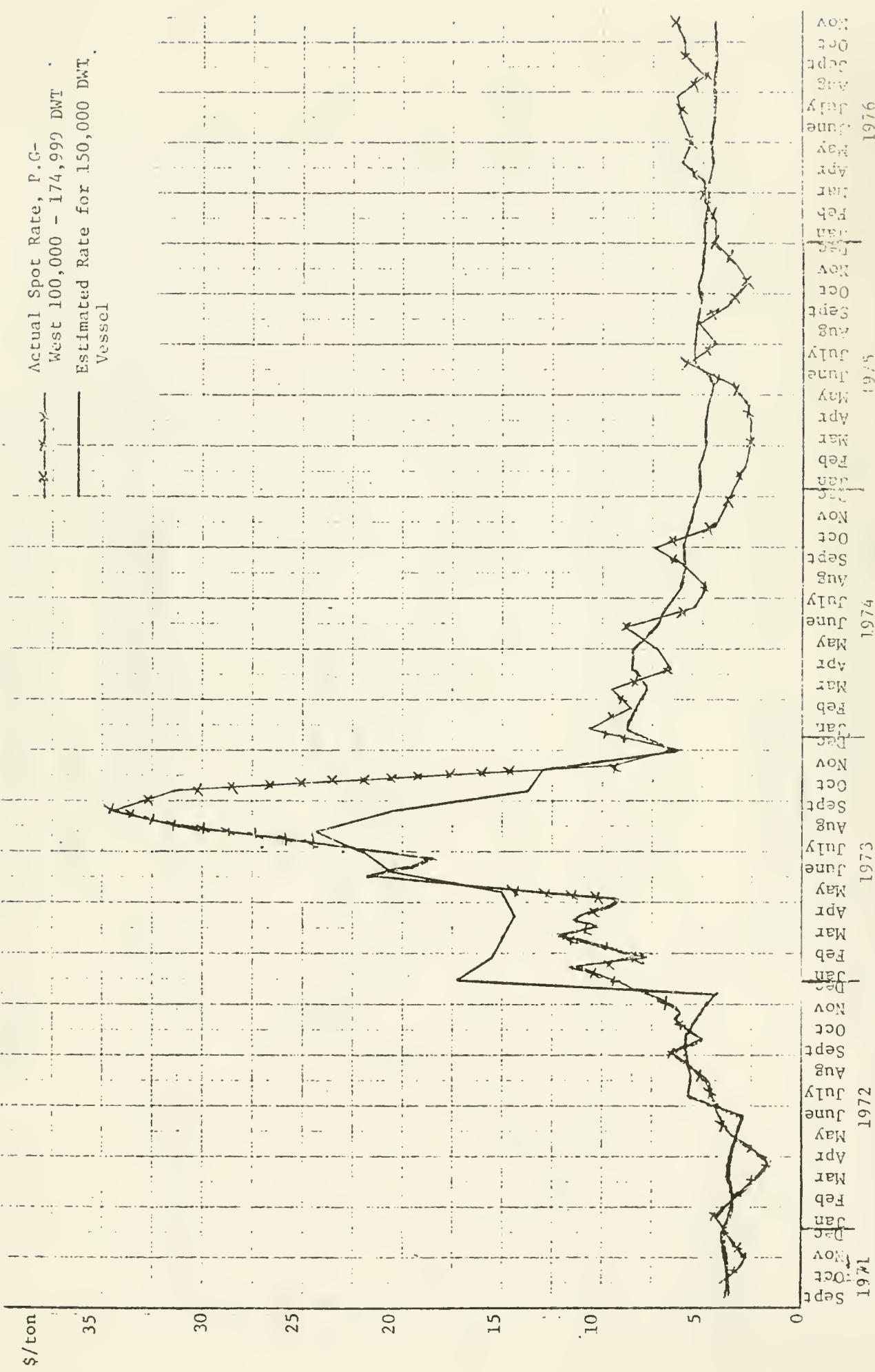


FIGURE 4 SINGLE VOYAGE FREIGHT RATES



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## Loss of VLCC Capacity During the Second Half of 1979

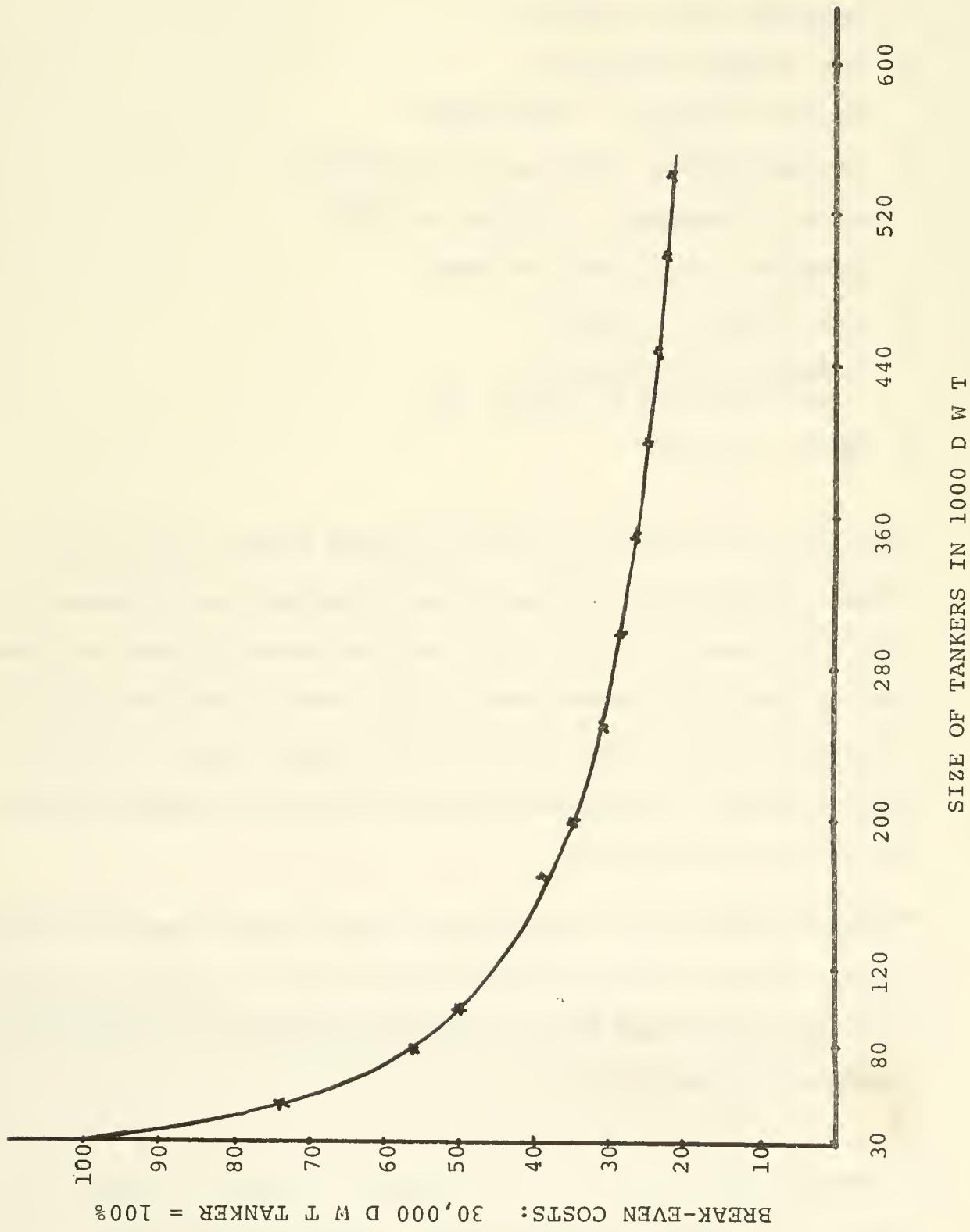
Tankers Over 200,000 DWT Only

<u>Cause</u>	<u>Tonnage in Million DWT</u>
1. Lay-up (20 vessels)	4.9
2. Slow Steaming <sup>a</sup>	33.8
3. Excess Port Time <sup>b</sup>	21.0
4. Separate Ballast Tanks/COW Retrofit and Unexplained Delays	3.5
5. Part Cargo	15.0
6. Total	78.2
7. Total Capacity Available	185.2
8. Underutilization (6 ÷ 7)	42.2%

<sup>a</sup>To save fuel. The savings are passed on to the charterer in terms of a lower rate (rental).

<sup>b</sup>Normal port time is four days per trip. The empirical average was 12.4 days. Assumption of five trips per year.

Source of Data: John I. Jacobs, February 1980, op. cit., pp. 6, 28 - 29.



Assumptions

1. Construction Costs: 1975\*
2. Operating Costs: March 1979
3. Run: Arabian Gulf/U.S.E.C.  
Round-trip Distance: 24,540 miles\*\*
4. Borrowed Capital: 70% of cost at 9% interest
5. Return on Investment: 11%, after tax of 50%
6. Operating: 11 1/2 months per year
7. Life of Vessel: 20 years
8. Probability of Unemployment  
over the life of the tanker: .09
9. Speed: 15.5 knots

\*Since not many vessels were ordered subsequent to 1975, we could not obtain a dependable cost of construction for various sizes subsequent to 1975. This, however, is not a major source of concern because the relevant costs are the specific vessel costs. What is more if inflation affects all sizes equally and to the extent that we are using an index rather than absolute dollars, the relationship between the costs of various sizes is for the most part preserved.

\*\* Tankers consume part of their capacity, because bunkers take away from the payload. Because of this and the fact that there are economies of scale in operating costs and port time, one cannot make a general statement that the longer the trip the more pronounced the economies of scale.

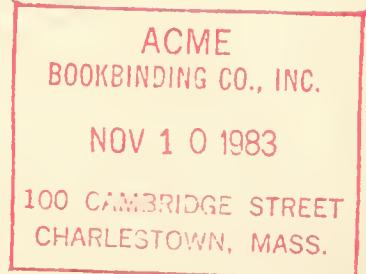
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Definition of Break-even Cost: The freight rate which will cover all the costs over the life of the vessel, under the postulated assumptions, and yield a return of 11% after taxes to the owners.



Date Due		
DEC 15 1984	NOV 13 1998	
FEB 20 1985	AUG 31 2001	
APR 19 1985		
JUN 5 1985		
JUL 15 1985		
MAR 25 '86		
APR 6 8 '86		
FEB 26 1990		
DEC 18 1989		
MAY 13 1990		

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Pindyck, Robert/The optimal production  
740960 D\*BKS 00132375



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Kochan, Thomas/Toward a behavioral mod  
741436 D\*BKS 00132381



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